1.5em

AA 272C: Global Positioning Systems
Problem Set 3

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Algorithm Sensor Fusion

Algorithm 1 Sensor Fusion EKF

Inputs:
    GNSS pseudoranges
    Satellite positions
    IMU odometry
    barometer measurements
Initialize:
    $\mathbf{T} \leftarrow$ concatenated and sorted timesteps
for $t \in \mathbf{T}$ **do**
    if odometry exists at t **then**
        Predict:
            $v_t \leftarrow$ imu odometry
            $\hat{\mu}_{t|t-1} = F\hat{\mu}_{t-1|t-1} + Bv_t$
            $P_{t|t-1} = F_t P_{t-1|t-1} F_t^T + Q$
    end if
    if GNSS exists at t **then**
        Update GNSS:
            $z_t \leftarrow$ GNSS measurements
            $\tilde{y}_t = z_t - h(\hat{\mu}_{t|t-1})$
            $K_t = P_{t|t-1} H_t^T (R + H_t P_{t|t-1} H_t^T)^{-1}$
            $\hat{\mu}_{t|t} = \hat{\mu}_{t|t-1} + K_t \tilde{y}_t$
            $P_{t|t} = (I - K_t H_t) P_{t|t-1} (I - K_t H_t)^T + K_t R K_t^T$
    end if
    if Barometer exists at t **then**
        Update Barometer:
            $z_t \leftarrow$ barometer measurements
            $\tilde{y}_t = z_t - h(\hat{\mu}_{t|t-1})$
            $K_t = P_{t|t-1} H_t^T (R + H_t P_{t|t-1} H_t^T)^{-1}$
            $\hat{\mu}_{t|t} = \hat{\mu}_{t|t-1} + K_t \tilde{y}_t$
            $P_{t|t} = (I - K_t H_t) P_{t|t-1} (I - K_t H_t)^T + K_t R K_t^T$
    end if
end for

EKF Model Update

For the state:

$$\hat{\mu} = \begin{bmatrix} x \\ y \\ z \\ \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix}$$

For the predict step, I will use:

$$\hat{\mu}_{t|t-1} = F\hat{\mu}_{t-1|t-1}$$

$$\hat{\mu}_{t|t-1} = \begin{bmatrix} 1 & 0 & 0 & \Delta t & 0 & 0 \\ 0 & 1 & 0 & 0 & \Delta t & 0 \\ 0 & 0 & 1 & 0 & 0 & \Delta t \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix}$$

For Q, I will use

$$\sigma = 0.03km/h * \frac{1000m}{1km} * \frac{1h}{3600s} * dt$$

$$Q = \begin{bmatrix} \sigma^2 & 0 & 0 \\ 0 & \sigma^2 & 0 \\ 0 & 0 & \sigma^2 \end{bmatrix}$$

For the update step, I will use

$$h = \begin{bmatrix} \sqrt{(x_1 - x)^2 + (y_1 - y)^2 + (z_1 - z)^2} \\ \sqrt{(x_2 - x)^2 + (y_2 - y)^2 + (z_2 - z)^2} \\ \sqrt{(x_3 - x)^2 + (y_3 - y)^2 + (z_3 - z)^2} \\ \sqrt{(x_4 - x)^2 + (y_4 - y)^2 + (z_4 - z)^2} \\ \sqrt{(x_5 - x)^2 + (y_5 - y)^2 + (z_5 - z)^2} \\ \sqrt{(x_6 - x)^2 + (y_6 - y)^2 + (z_6 - z)^2} \end{bmatrix}$$

$$H = \begin{bmatrix} \frac{-(x_1-x)}{\sqrt{(x_1-x)^2+(y_1-y)^2+(z_1-z)^2}} & \frac{-(y_1-y)}{\sqrt{(x_1-x)^2+(y_1-y)^2+(z_1-z)^2}} & \frac{-(z_1-z)}{\sqrt{(x_1-x)^2+(y_1-y)^2+(z_1-z)^2}} \\ \frac{-(x_2-x)}{\sqrt{(x_2-x)^2+(y_2-y)^2+(z_2-z)^2}} & \frac{-(y_2-y)}{\sqrt{(x_2-x)^2+(y_2-y)^2+(z_2-z)^2}} & \frac{-(z_2-z)}{\sqrt{(x_2-x)^2+(y_2-y)^2+(z_2-z)^2}} \\ \frac{-(x_3-x)}{\sqrt{(x_3-x)^2+(y_3-y)^2+(z_3-z)^2}} & \frac{-(y_3-y)}{\sqrt{(x_3-x)^2+(y_3-y)^2+(z_3-z)^2}} & \frac{-(z_3-z)}{\sqrt{(x_3-x)^2+(y_3-y)^2+(z_3-z)^2}} \\ \frac{-(x_4-x)}{\sqrt{(x_4-x)^2+(y_4-y)^2+(z_4-z)^2}} & \frac{-(y_4-y)}{\sqrt{(x_4-x)^2+(y_4-y)^2+(z_4-z)^2}} & \frac{-(z_4-z)}{\sqrt{(x_4-x)^2+(y_4-y)^2+(z_4-z)^2}} \\ \frac{-(x_5-x)}{\sqrt{(x_5-x)^2+(y_5-y)^2+(z_5-z)^2}} & \frac{-(y_5-y)}{\sqrt{(x_5-x)^2+(y_5-y)^2+(z_5-z)^2}} & \frac{-(z_5-z)}{\sqrt{(x_5-x)^2+(y_5-y)^2+(z_5-z)^2}} \\ \frac{-(x_6-x)}{\sqrt{(x_6-x)^2+(y_6-y)^2+(z_6-z)^2}} & \frac{-(y_6-y)}{\sqrt{(x_6-x)^2+(y_6-y)^2+(z_6-z)^2}} & \frac{-(z_6-z)}{\sqrt{(x_6-x)^2+(y_6-y)^2+(z_6-z)^2}} \end{bmatrix}$$

$$\sigma = 8mR = \begin{bmatrix} \sigma^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma^2 \end{bmatrix}$$